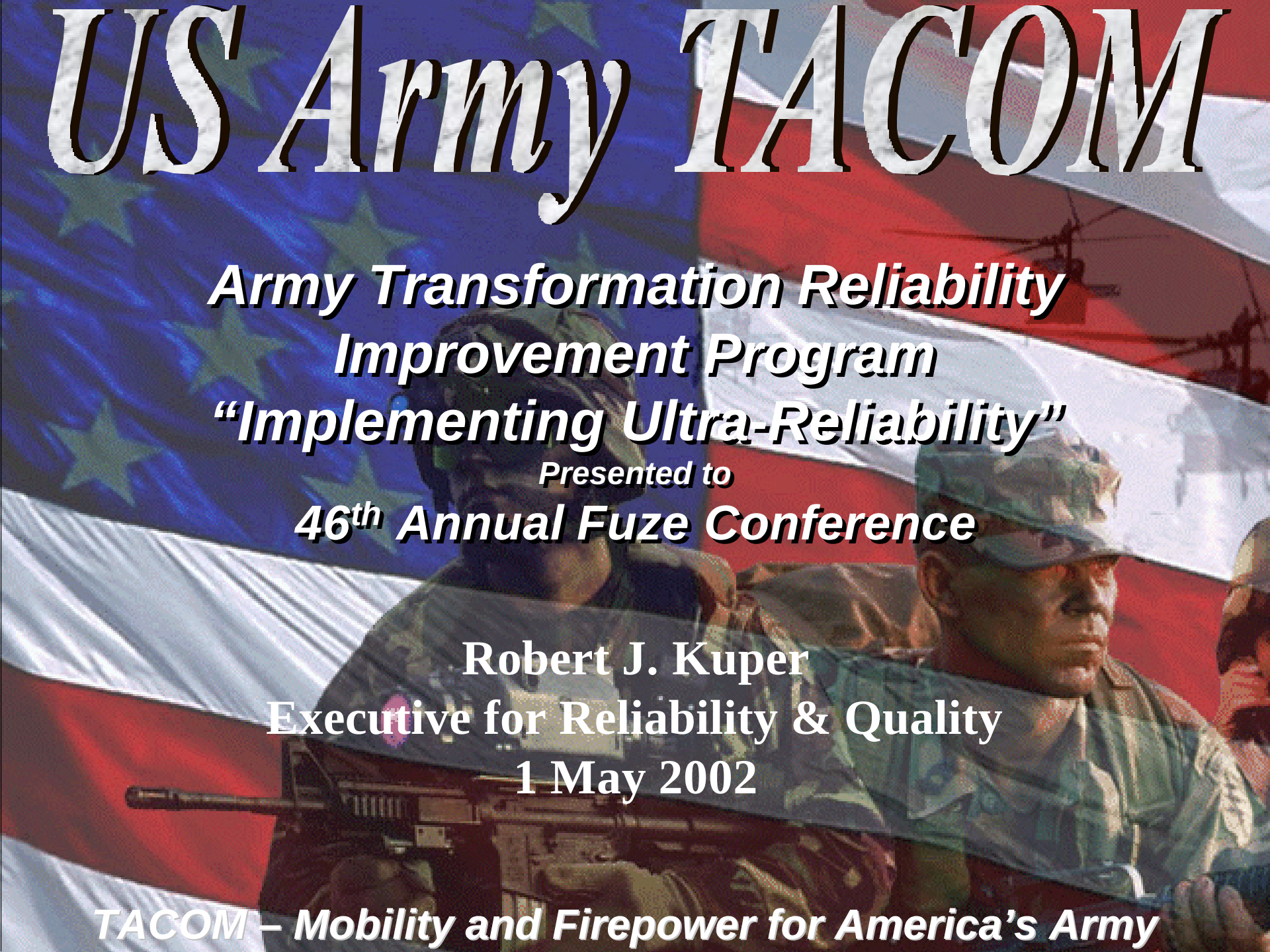


US Army TACOM

Army Transformation Reliability Improvement Program "Implementing Ultra-Reliability"

Presented to

46th Annual Fuze Conference

Robert J. Kuper
Executive for Reliability & Quality

1 May 2002

TACOM – Mobility and Firepower for America's Army

Outline

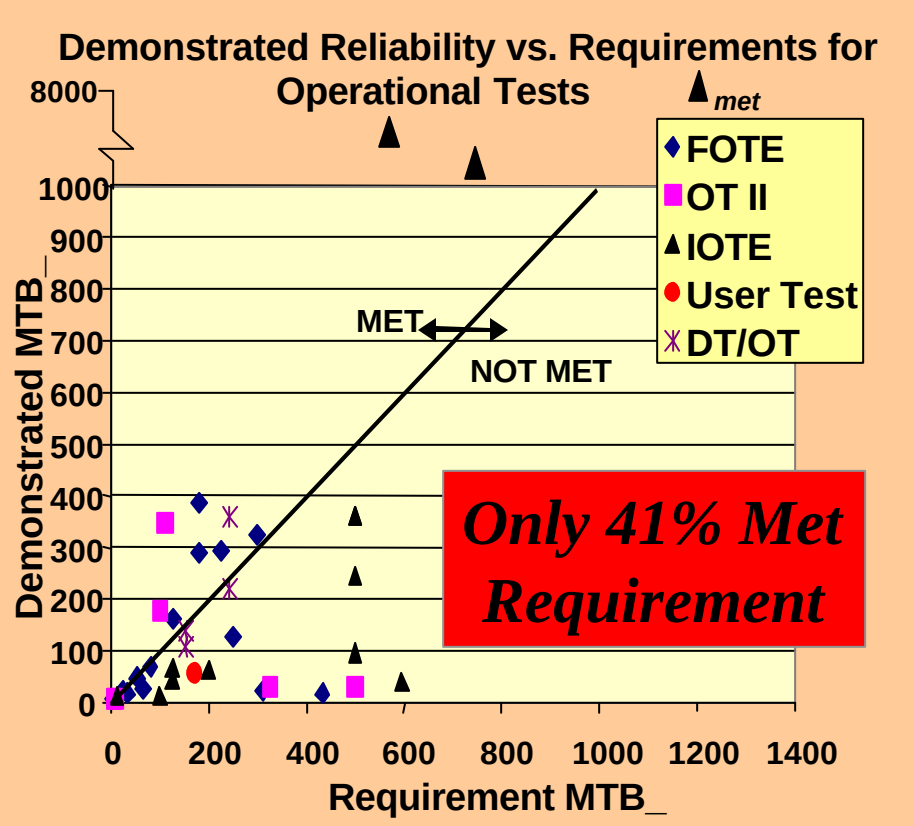
- **The Army's Reliability Problems**
  - What are the Concerns & Issues?
- **The Requirements for Transformation**
  - What are the Challenges?
- **The Solution Set**
  - The Current Reliability Paradigm
  - Changes to the Standards of Practice
  - Road Map to "The New Paradigm"
- **The Technical Issues & Challenges**
- **Evolving Strategies to Achieve "Ultra-Reliability"**
  - Disciplines
    - Six Sigma
    - Capability Maturity Model
  - Change Management

Background

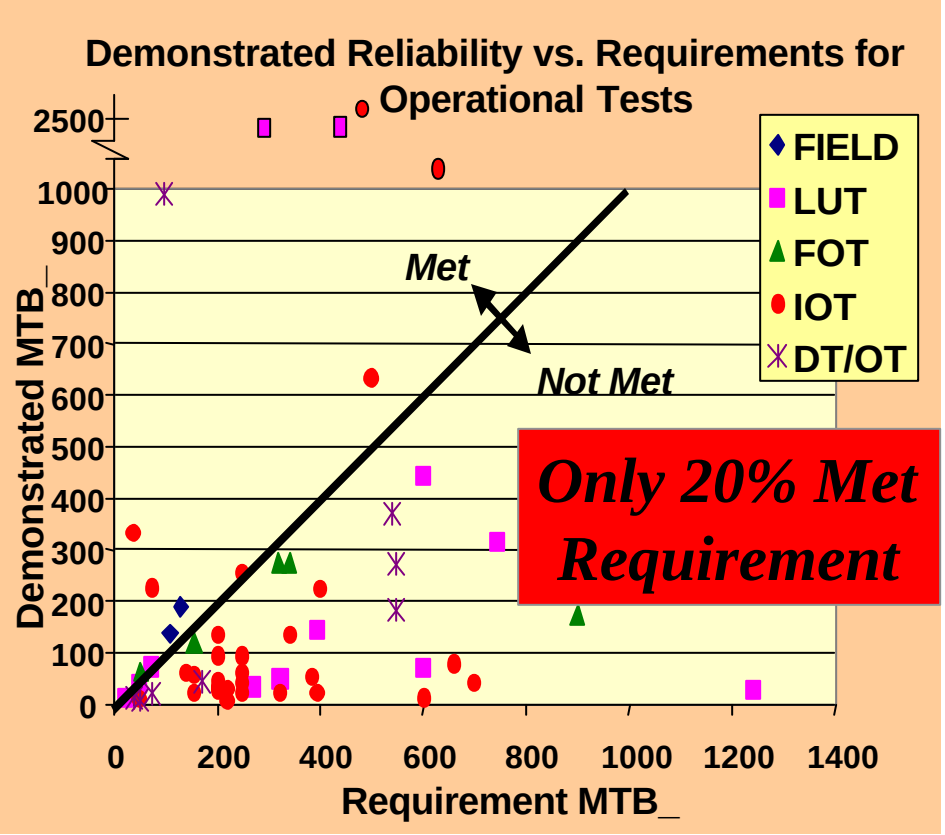
- **Major Army Problem**
  - Poor Demonstrated Reliability in Operational Testing
    - ’85-’95 59% failure rate in Operational testing
    - ’96-’00 80% failure rate in Operational testing
- **Systemic Problems with RAM Engineering Processes**
  - Poor performance with older technologies
  - Concerns for FCS and Objective Force tech infusions
    - Improve on the Basics
    - Utilize the Advanced Tools, Techniques and, Methods
  - Root Cause
    - Eroding Core Competencies
    - Reduced Visibility of the RAM engineering Discipline AND reduced presence of Senior RAM Engineer in Design, Process, T&E, Log/Supportability Decision(s) Making Processes.
- **MNS for OBJ Force: Zero System failures in 7 Day Medium to High OPTEMPO Combat Pulse without maintenance, Logistical or rearm support.**
  - Today’s systems are “Reliable”…. Right?
    - M1 @ NTC 7 day combat pulse….46% system failure rate at 3 days……
- **CASCOM Thrust for AAN in late ’90’s – “Ultra-Reliable Systems”**
  - Need World class Reliability, Best Practices, State of the art techniques and tools
- **Army Workshop on Ultra-Reliability, AMSAA studies, CASCOM/Rand Studies**
  - PEO Integration & Implementation for the Future – Six Sigma Framework
  - TACOM Executive for Reliability & Quality - Change Agent

Our Reliability Track Record Is Not Good

1985-1995



1996-2000



Most Of Our Systems Fail To Achieve Reliability Requirements In OT

And The Trend Appears To Be Downwards

source: ATEC/AEC

Our Current 'Reliable' Systems Are Not Reliable Enough

FCS – Where we need to be:

" A deployed FCS force must be capable of operating, at a medium to high optempo, for at least one week without maintaining, rearming or resupply." (Draft MNS)

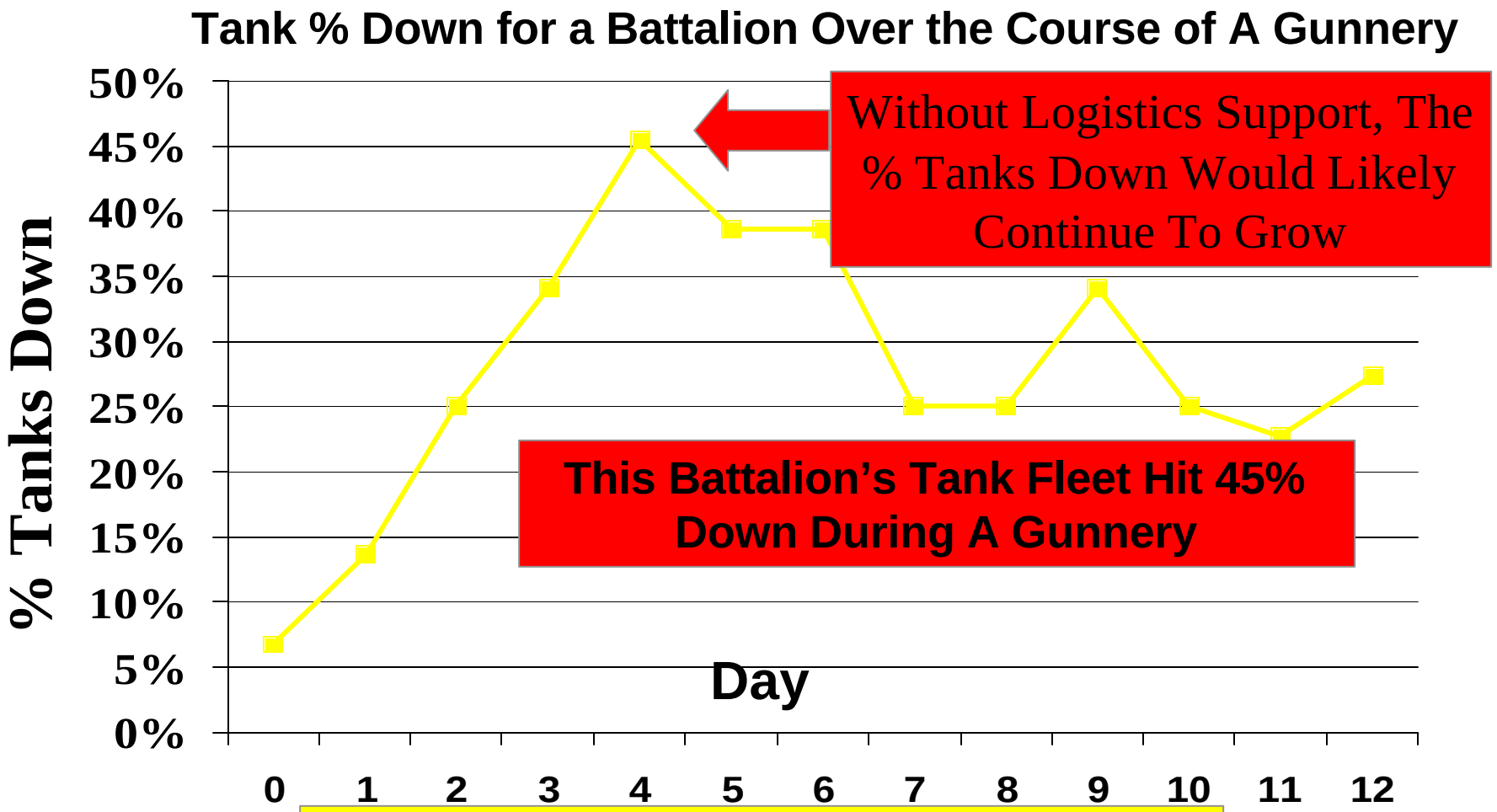
Where we are:

- 46% of M1A1's have a mission critical failure in 3 days during a week of medium to high OPTEMPO at NTC
- 40% for M2's during 7 day combat pulse.

Army Reliability Practices Need To Change If We Are To Achieve Goals Like That Of The FCS

source: AMSAA

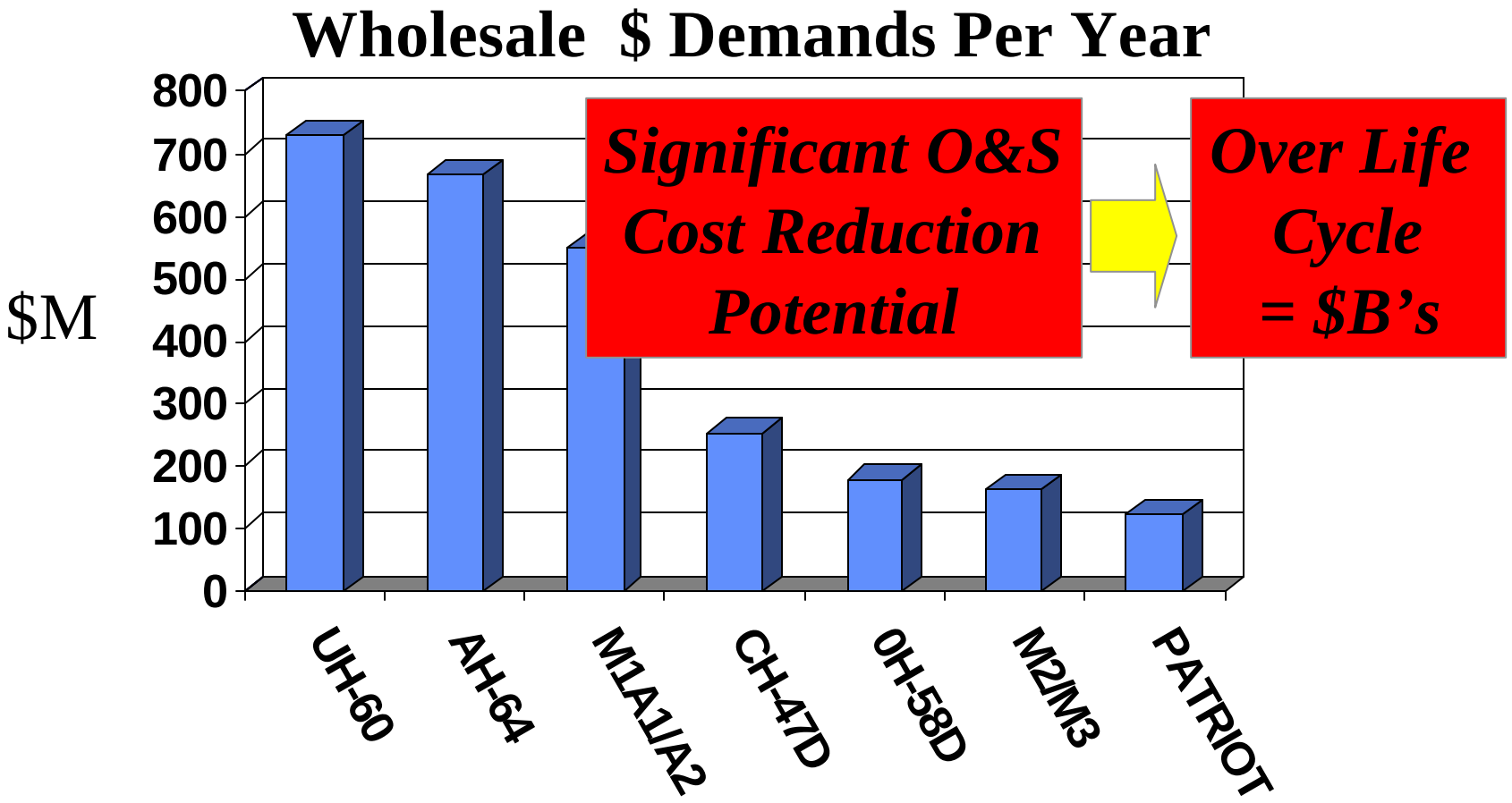
Better Reliability Is Needed To Reduce Log Footprint



With Performance Like This, Systems Require A Large Logistics Footprint

source: RAND

And The Cost To Support Our Current Reliability Levels Is Large



source: JUNE 00 STRAT

Problems with Ammunition

General Issues

- Stockpile is Aging rapidly. Average age close to 15-20 years. Many different failure mechanisms
- Unique applications causing accelerated degradation – PREPO Storage on ship and on land, Uploaded Ammo, Desert Storage
- Significant Shortfall in Precision & Preferred munitions
- Industrial Base significantly reduced over the past 10 years
- Surge & Replenishment are questionable
- Single source for many critical components
- Mantech investments only by Congressional plus-ups
- Training consuming 85 to 95% of Ammo budget – Little Modernization, Meaningless unfulfilled AAO's
- Surveillance grossly under-funded – NO Predictive capability

Specific Problems

- DU Corrosion
- Combustible cases – swelling, separation
- HE Melt-pour – Artillery & Mortar
- Mixed Propellant grains – cause accelerated degradation
- Propellant bag deterioration – Incompatibility of clothe & propellant degradation products
- Ineffective Training - Copperhead

Historical Problems with Fuzes & Firing Mechanisms

"Just a few examples"

- M577 – Lubricant drying with age and temperature
- M732 – Battery leakers
- M762 – Uncured Potting
- Lance Missile – Tantulum capacitors
- Reserve Batteries – Power density, rise time, active time, eccentric dynamic motion
- Gator, GEMSS, Volcano – Tungsten Bridge wires fuses
- M831 Tank Proximity Fuze – Chip on Board
- FASCAM – HED Batteries – process problems
- Pyrotechnic aging and processing problems
- M582 Fuze - Inflight premature detonations with M650 Rocket-On
- Etc….etc…..

Bottom-line: Have not understood Physics of Failure and Aging Mechanisms. Components, Design, Process, Aging, Human Factors, Environments, etc… All Causes or Drivers of Safety, Reliability and Availability problems.

New Ammo Components & Technologies Where Reliability must be well Understood

Submunitions
Self Destruct Fuzes
Autonomous Launch Platforms
Seismic & Acoustic Sensors
IR Target Sensors
Polynitrocubanes
Laser Designation
Autonomous Search - Kill Mechanisms
Software in every system
Chip-on-Board
Ball Grid Array

Microelectronics
Micro electro-mechanical MEMS
Combustible Cases
Composites
Plastics - Organics
Power Supplies
Ignition Trains
Soldering Technologies
COTS - parts and processes
Rocket motors & propulsion
RAID, Parachute, RAD materiels
Identification Friend or Foe (IFF)

And Then, Must be able to Assure Reliability of Systems of Systems

"Defining the Problems & Issues with Reliability & RAM Engineering"

Initial Data Sources – 3 years of effort invested

- **Workshops on Reliability and Ultra-Reliability.**
- **Continuing AMSAA Reliability Studies for MILDEP '00 – '01 - GEN Kern and now '02 - LTG Caldwell**
- **ATEC/DTC Studies**
- **PEO/PM Results**
- **Operational Support Command – Readiness Assessments**
- **Six Sigma Program @ PEO-GCS, PEO-Ammo & TACOM-ARDEC**
- **etc……..**

Workshops & Reliability Studies – Findings

- ***Processes and Areas which require corrective actions:***
  - **Policy**
  - **Reliability Tools**
  - **T&E and M&S**
  - **Training**
  - **Supportability**
  - **Systems Engineering**
  - **Program Management**
  - **Field Data Feedback**
  - **Contracting for Reliability**
  - **Etc…….**

Primary Focus on <u>Defining</u>
Some emphasis on <u>Measure, Analyses</u>
<u>Improvement</u> and
<u>Control</u>

- ***Need for Army Integration Lead***

The Current Paradigm – We accept Failure because we know we can Fix things
Hence the enormous Logistical Tail

Some Proposed Solutions

"To attain Ultra-Reliability"

- **Redundancy**
- **Focused testing**
- **Designed-In Ultra-Reliability - Inherent reliability**
- **Diagnostics and Prognostics**
- **Design Modularity – On-board Spares**
- **Commonality – Common Chassis, Common Components**
- **Reduced Weight equals reduced failures and reduced logistics**
- **Better Trained, More Responsive - Logistical Supportability**
- **Contracting for reliability**

No Single Silver Bullet
Requires a combination of strategies and More

Requires a Paradigm Change

Strategy to Achieve New Ultra-Reliability Paradigm

- Identify the Issues/Problems with current "Standard of Performance"
- Design the Road Map to Ultra-reliability – World-class Tools/Processes
- Apply Six Sigma Discipline to entire effort
- Build Core Competencies – Use CMMI for Organizational Success
- Run Pilot Program on FCS and RECAP Programs
- Champions: GEN Kern, CG, AMC and LTG Caldwell, MILDEP for AAE, LTG Mahan, DA DCSLOG
- Change Agent: Bob Kuper, Executive for Reliability & Quality, TACOM
- Technical Experts:
  - AMSAA, CASCOM, LIA, Contractors/Industrial Base/Academia
- **Peer Review – National Academy of Science – Nat'l Labs**
- Create the Infrastructure to tie in Technical Expertise,FCS LSI, Industrial Base and User Interfaces
- Deploy New Paradigm via Virtual Framework of the AMC Quality Federation!
  - Sallie Flavin, Asst DCS-RDA Quality Champion @ AMC
  - Steve French – ASAALT Champion for Reliability

Official Army Pilot Program

- Create a Partnership with Key Organizations that will make the Ultra-Reliability Paradigm a functional reality for LC Assurance
- Key partners: AMSAA, CASCOM, TACOM, PEO's, NASA, National Labs, Industry, Professional Societies
- Official Pilot Program sanctioned by AAE & MILDEP – assures resources and visibility
  - Quarterly reviews with MILDEP
  - Look at all FCS and Army RECAP Programs
- Approval targeted for June 2002

Areas of Focus

- **Create a New Standard of Practice for a "Newly evolving Paradigm"**
- **New Paradigm – Assures Pulse Reliability for the FCS - Zero System Failures in 7 Day Combat Pulse with rapid Maintenance Cycle preceding next Pulse.**
- **Based on Physics of Failure – Predictive Engineering**
- **Use the Basics, Advanced & Best Proven Tools**
- **Invest in the Best technologies**
- **Visibility of the RAM Engineering Discipline within Systems Engineering**
  - ***In LC Cost, Performance, Supportability, T&E, M&S…..***
- **Visibility of Senior RAM Engineer in Design and Process Decision Making. "Co-equal" with lead Designer**
- **"EARLY" - RAM Engineering in Concept Development**
- **Continuous Reliability Growth Focus**

Ammo Implications:

Critical component of the System of Systems Approach

Requires Very High Inherent Design Reliability

Must be resistant to degradation given frequent deployments

Durability - Withstand varied Environmental Exposures, Process Control

Apply sensors & tracking technology for ITV, TAV and Diagnostic/Prognostics

AMSAA Inputs

- Physics of Failure
  - Electronics
  - Mechanical

Designing In Reliability

- Prognostics
- Onboard Spares & Redundancy Assessments

Potential FCS Reliability Enablers

- Reliability Case Training
- DAU Reliability Training
- Reliability Incentives

Contracting for Reliability

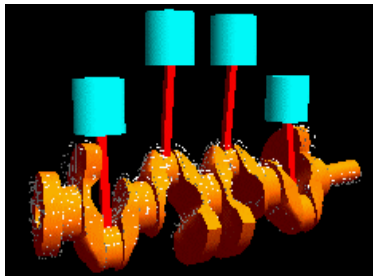
- Systems-of-Systems Modeling
- Reliability Growth & Test Design

Reliability Modeling

- FCS Reliability of Technology Assessments

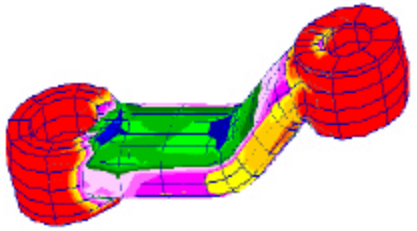
Reliability Challenges

Physics of Failure Software Tools

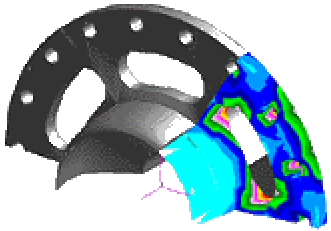


Solid Modeling Tools

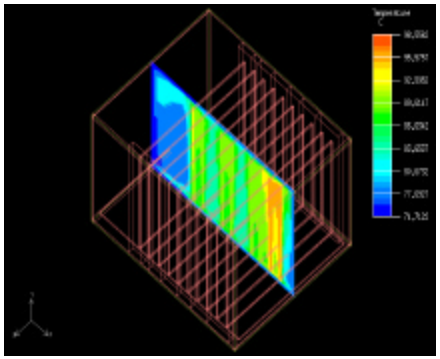
Dynamic Simulation Tools



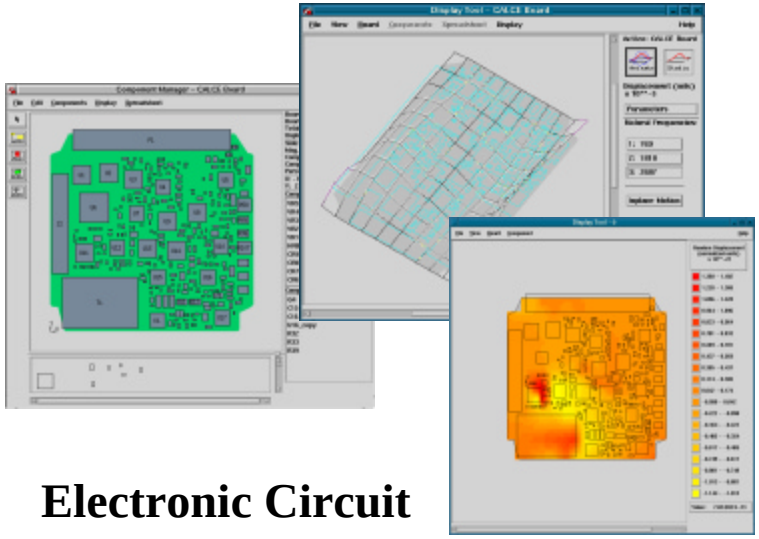
Finite Element Modeling Tools



Fatigue Analysis Tools



Thermal Fluid Analysis Tools



Electronic Circuit Card and IC Toolkits

Mechanical Physics of Failure - Dynamic Fatigue Analysis

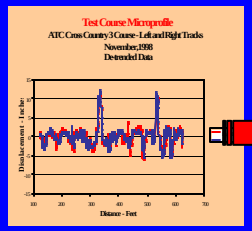
Pro/E

Solid Modeling

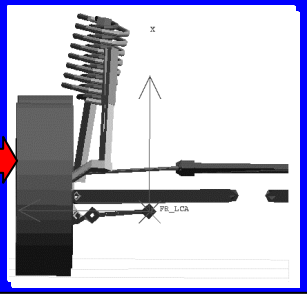
Dynamic Load Analysis

DADS

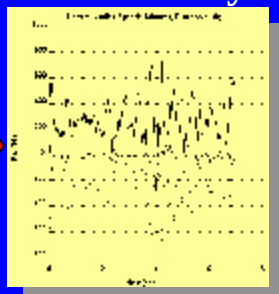
Terrain Model



System Model



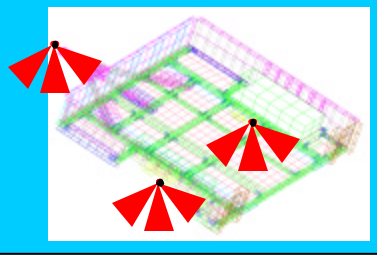
Dynamics Analysis



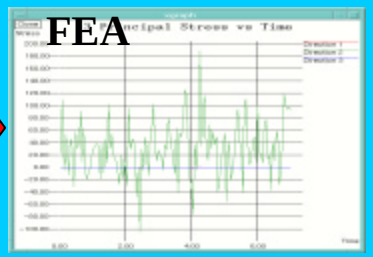
Component Stress Analysis

NASTRAN

FE Model



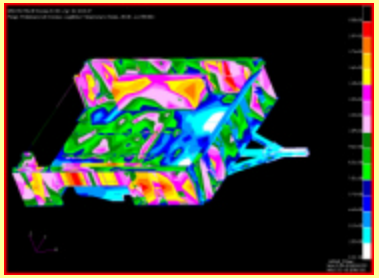
FEA



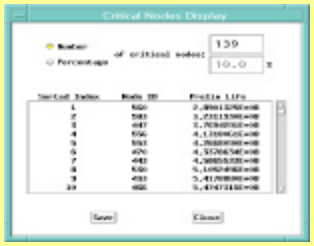
Reliability Analysis

DRAW

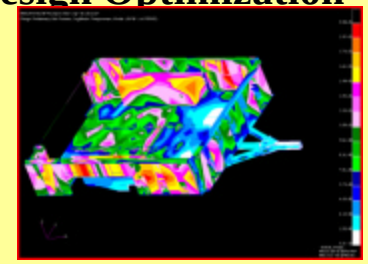
Fatigue Life Assessment



List of Critical Nodes

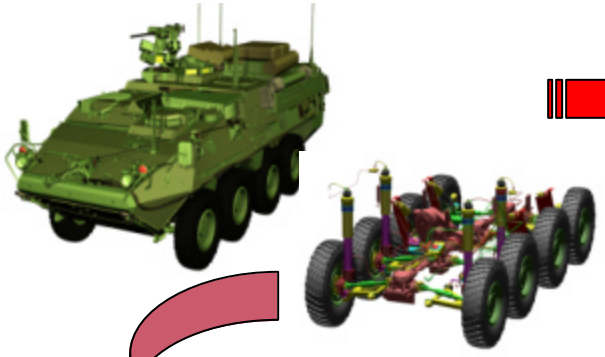


Reliability Based Design Optimization



IAV Engineering Analysis Team (EAT)

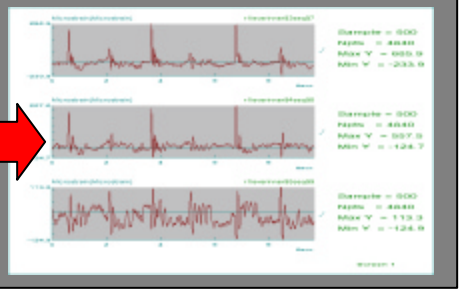
CAD



Test & Evaluation

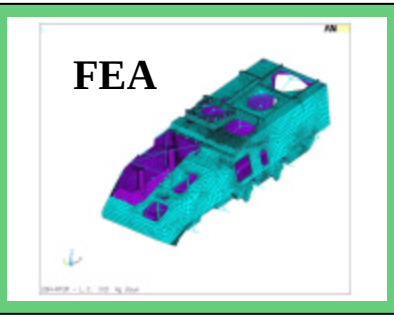
Automotive Durability

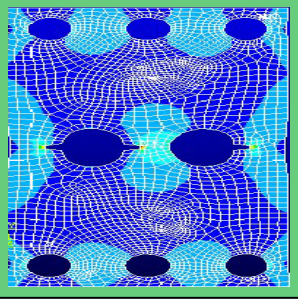
Strain Time History

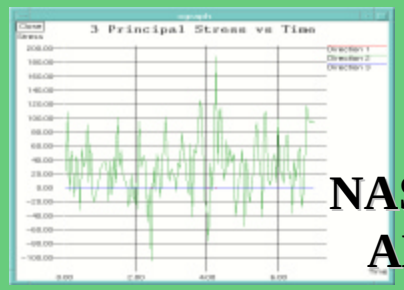


Component Stress Analysis

FEA





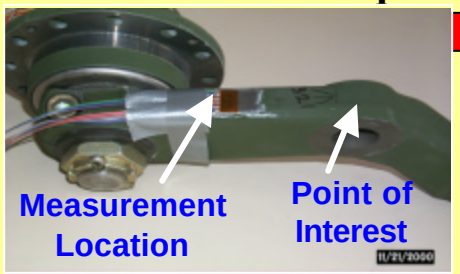


NASTRAN
ANSYS

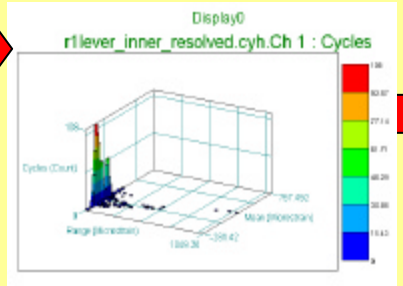
Component Durability Analysis

nCode

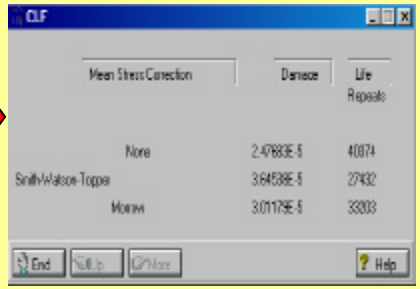
Stress Correlation - FEA or Classical Techniques



Rainflow Analysis



Service Life Prediction



CASCOM – TRADOC Inputs

- **Logistical Strategies**
  - Maintainability, On-board spares
  - Prognostics and Diagnostics
- **Field Data Feedback**
  - Failure data from weapons, vehicles and equipment
  - Focus for Designed-In Reliability
  - Studies of Pulse reliability impacts and strategies
- **Training & Doctrine – Requirements development**
  - Supportability ICT
  - RAM ICT

TACOM-ARDEC Inputs

- **Lead Change Agent – Program Coordinator**
- **Six Sigma Lead**
- **Reliability Core Competency Development**
- **AMC Quality Federation Deployment**
- **PEO/Program Management Interfaces**
- **Technical Specialty areas:**
  - Reliability Engineering Methods
  - Predictive Engineering & PoF LC Strategies
  - LC Environmental Analyses (MILSTD 810F)
  - Accelerated Life Testing & Aging sciences/protocols
  - Predictive Model Development
  - Program Management/Systems Engineering
  - Core Competency Development
  - Organizational and Process Improvement thru CMMI

Why PoF & Predictive Engineering?

PREMATURE STOCKPILE DETERIORATION

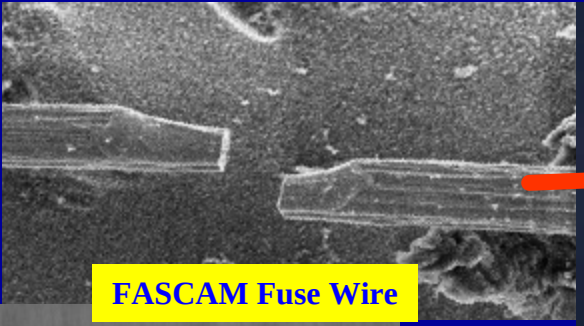
AS A
RESULT
OF

DESIGN & PRODUCTION DEFICIENCIES
&
TRANSPORTATION & STORAGE CONDITIONS

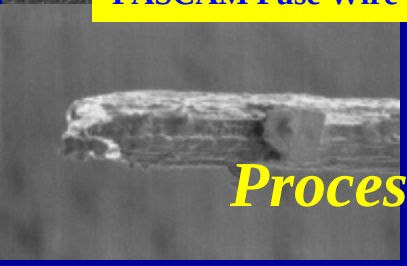
A FUNCTION OF:

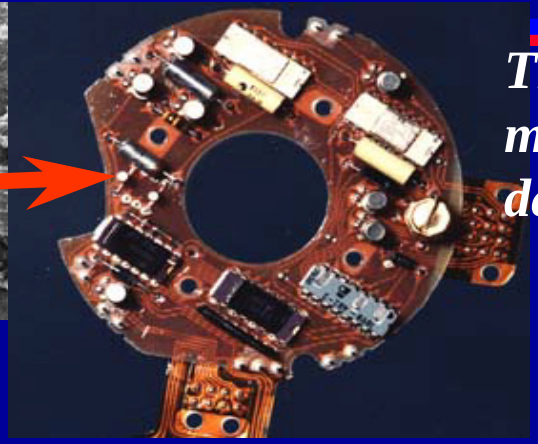
not understanding the "real" environments
&
not using adequate life cycle tools to assure and assess materiel robustness against premature failure/deterioration

The Army has experienced significant materiel losses through undetected degradation during deployment



FASCAM Fuse Wire



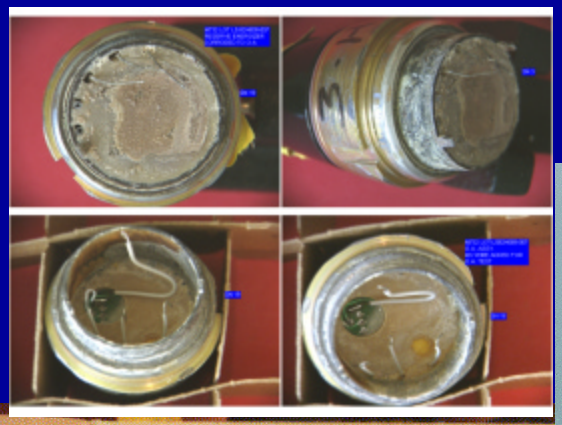


Process Sensitive ...

Exudate

Deterioration Sensitive ...

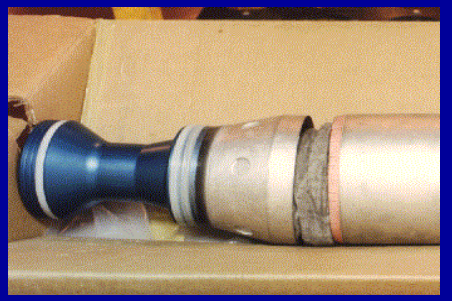
Corrosion

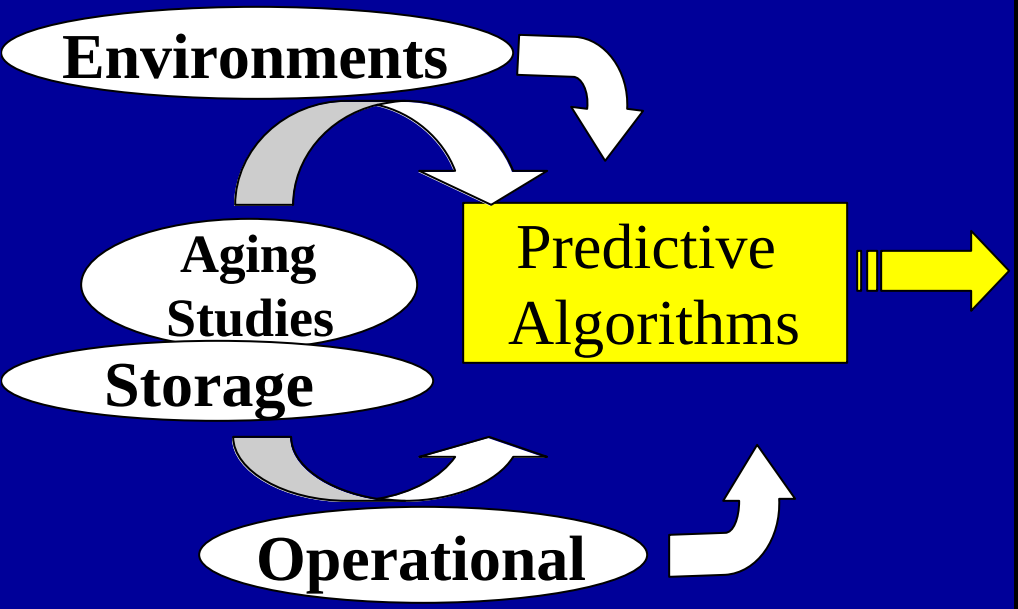


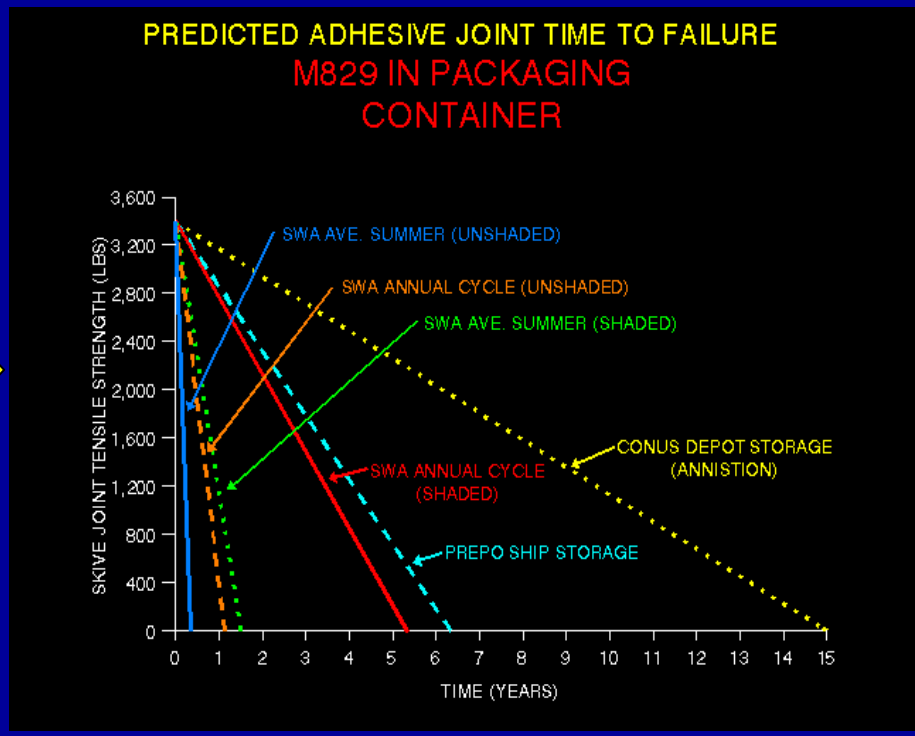
Marginal Design…

Skive Glue Joint

Life Cycle Analysis – Physics of Failure based
Aging Studies - Model Development

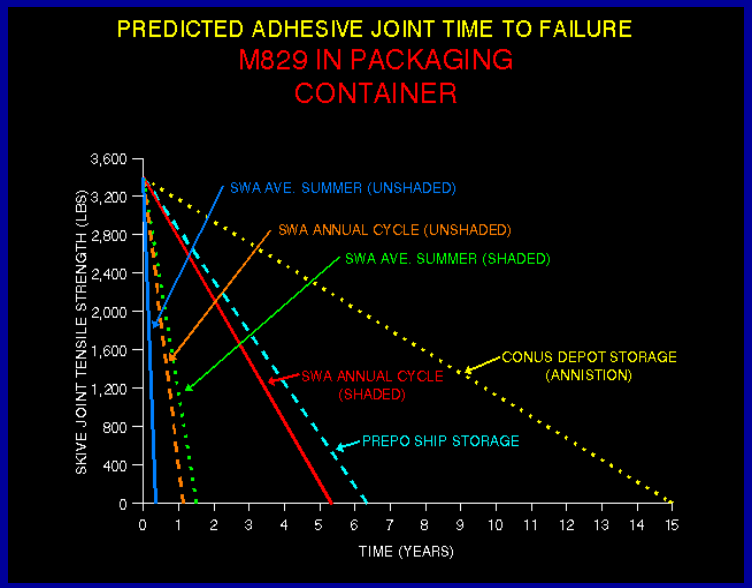






Life Cycle Analysis
Model Applications

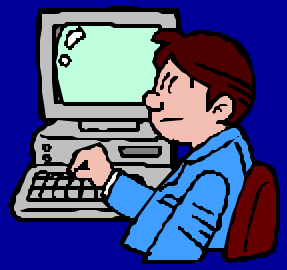
Physics of Failure Life Limiting Components



Improve the Design

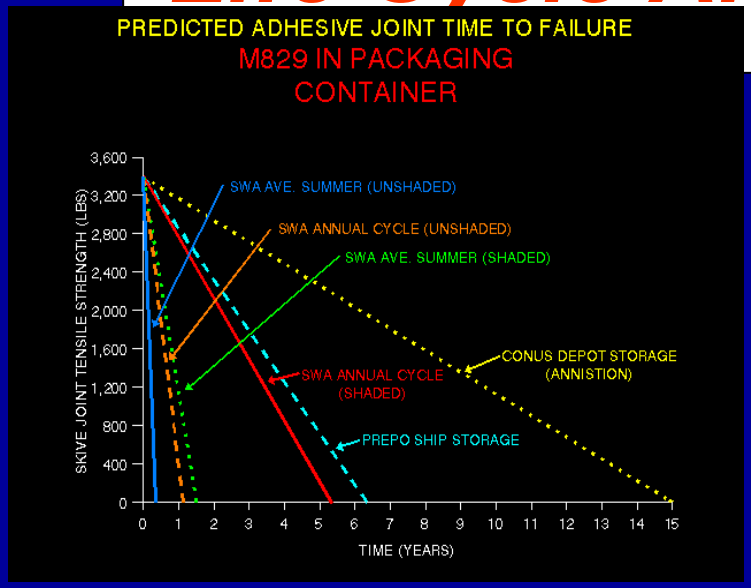
Control Processes

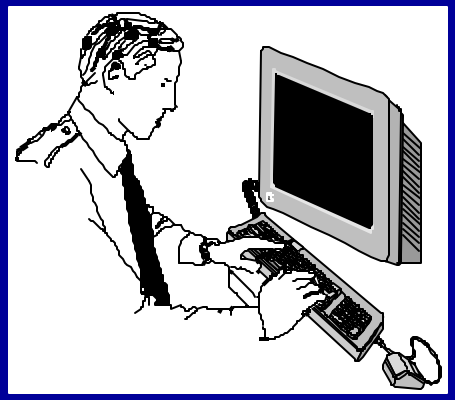
Predictive Algorithms



Optimize Stockpile Management
- **Sustainment**
- **Readiness**

Life Cycle Analysis - Sustainment

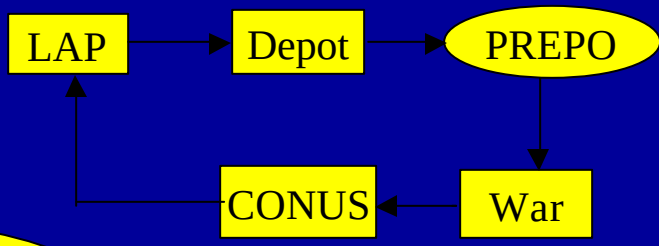




Life Cycle Simulation

ITEM Manager PEO/PM/SMCA

- **Total LC Log Process**
- **Total Ownership Costs**
- **Cost As an Independent Variable (CAIV)**



- **Surveillance Frequency**
- **Maintenance**
- **Condition Code**
- **Priority Usage**
- **Prepositioning**
- **Foreign Military Sales**
- **Demil**
- **Obsolescence**

Decision Morphology

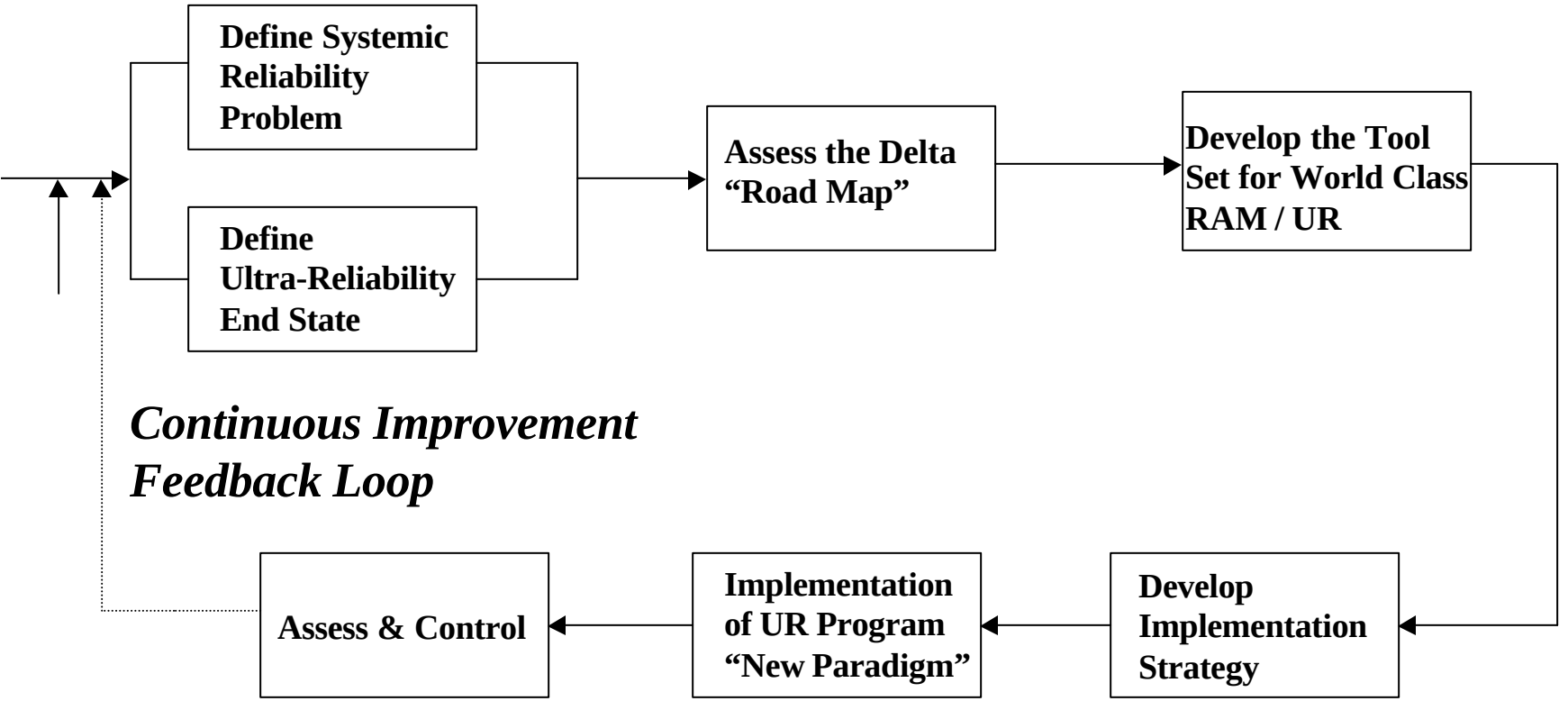
Disciplined DMAIC Process

Define, Measure, Analyze, Improve, Control

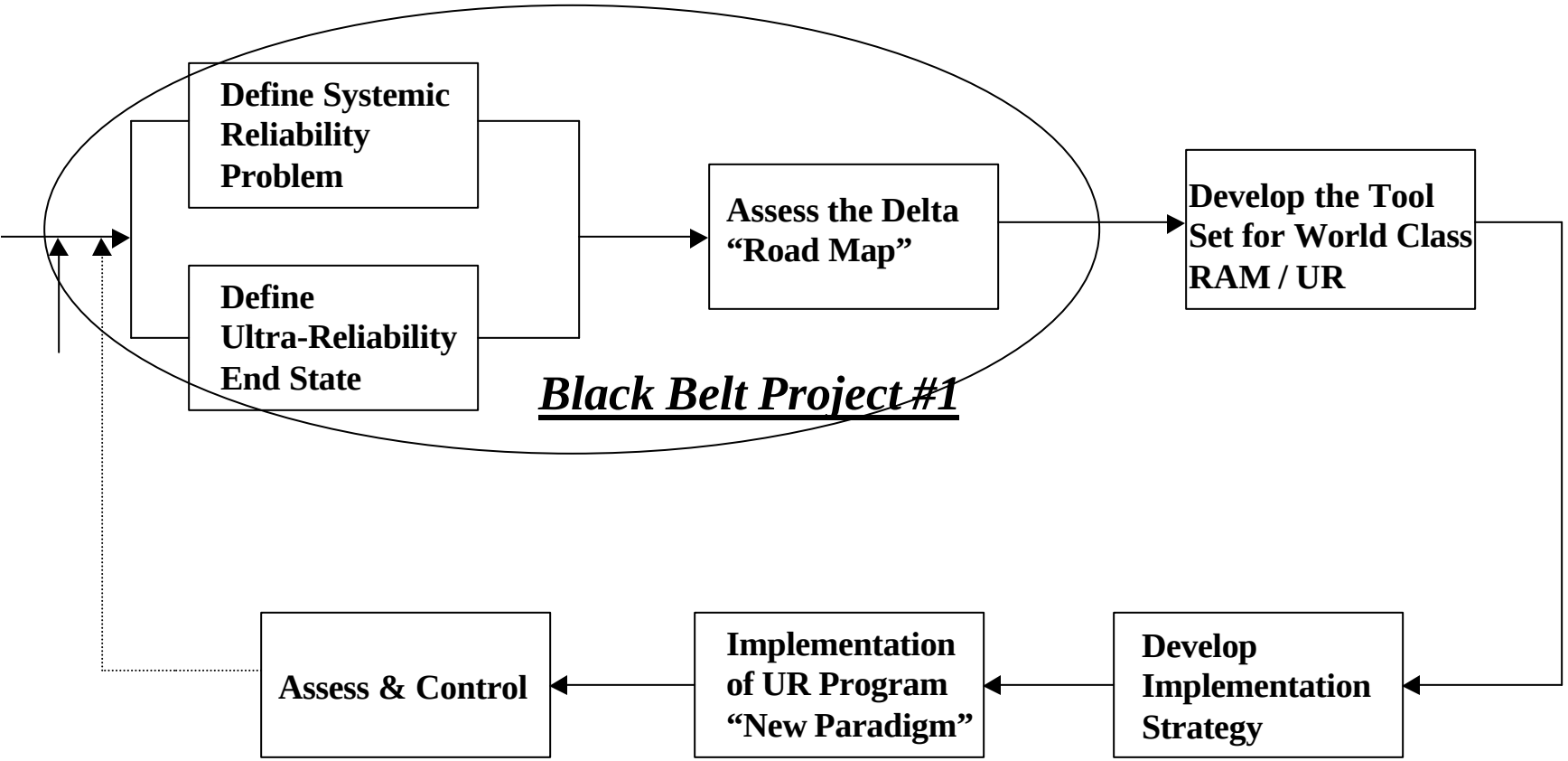
Objectives

- ***Army Program:***
  - **Correct Army's Systemic Reliability Problems**
  - **Reform the application of the RAM Engineering Discipline**
  - **Create and Implement A New Paradigm for LC Assurance**
  - **Create and Implement the Army's "Ultra-Reliability" or Transformation Reliability Improvement Program via Official Army Pilot Programs**
  - **Institute a Continuous Improvement Process**
- ***Black Belt Project # 1:***
  - **Develop an Army Program for the Application of State-of-the-Art RAM Engineering Discipline.**
    - **—Identify HOW to Correct the Systemic Problems**
    - **—Baseline Program for UR Achievement in the Future Combat System.**
  - ***Design the Roadmap***

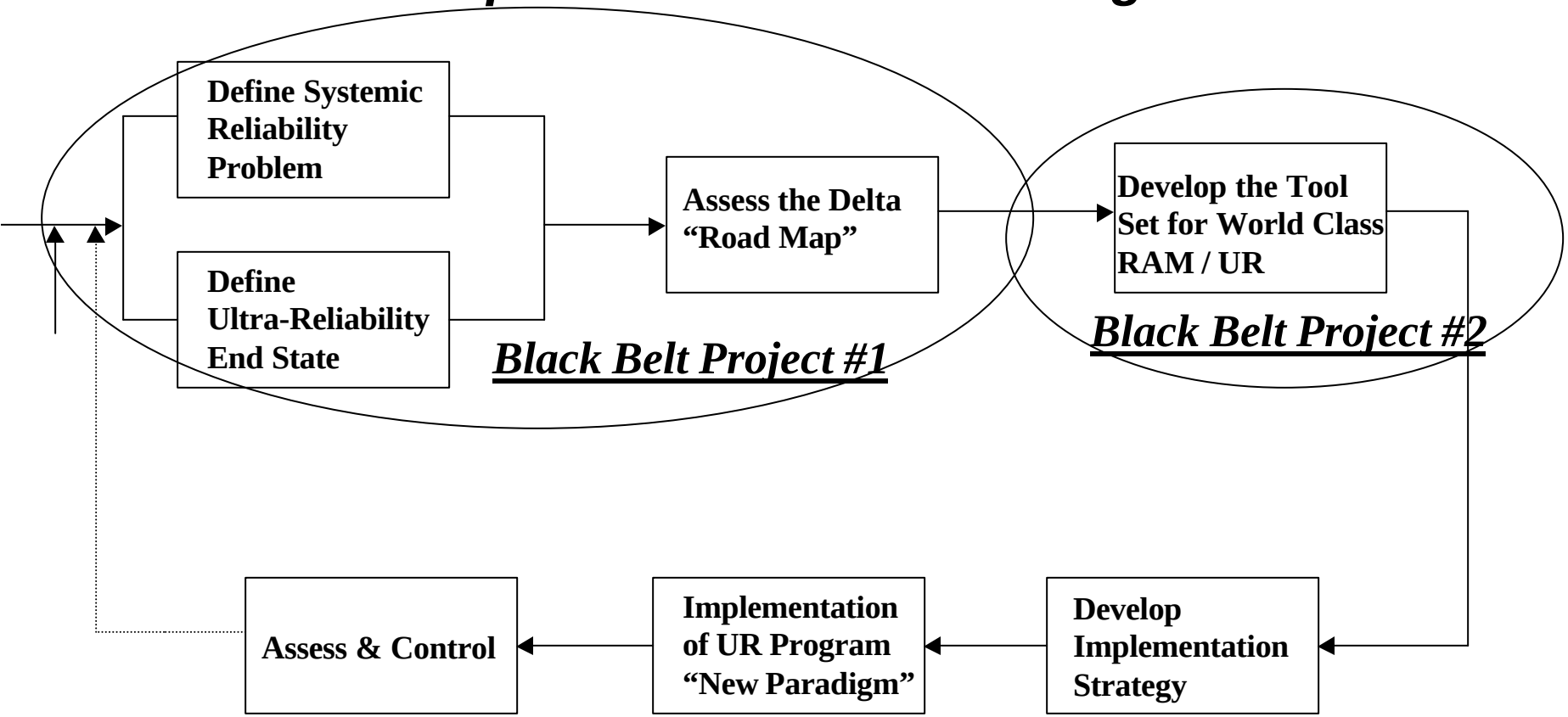
Simplified Process Flow Diagram



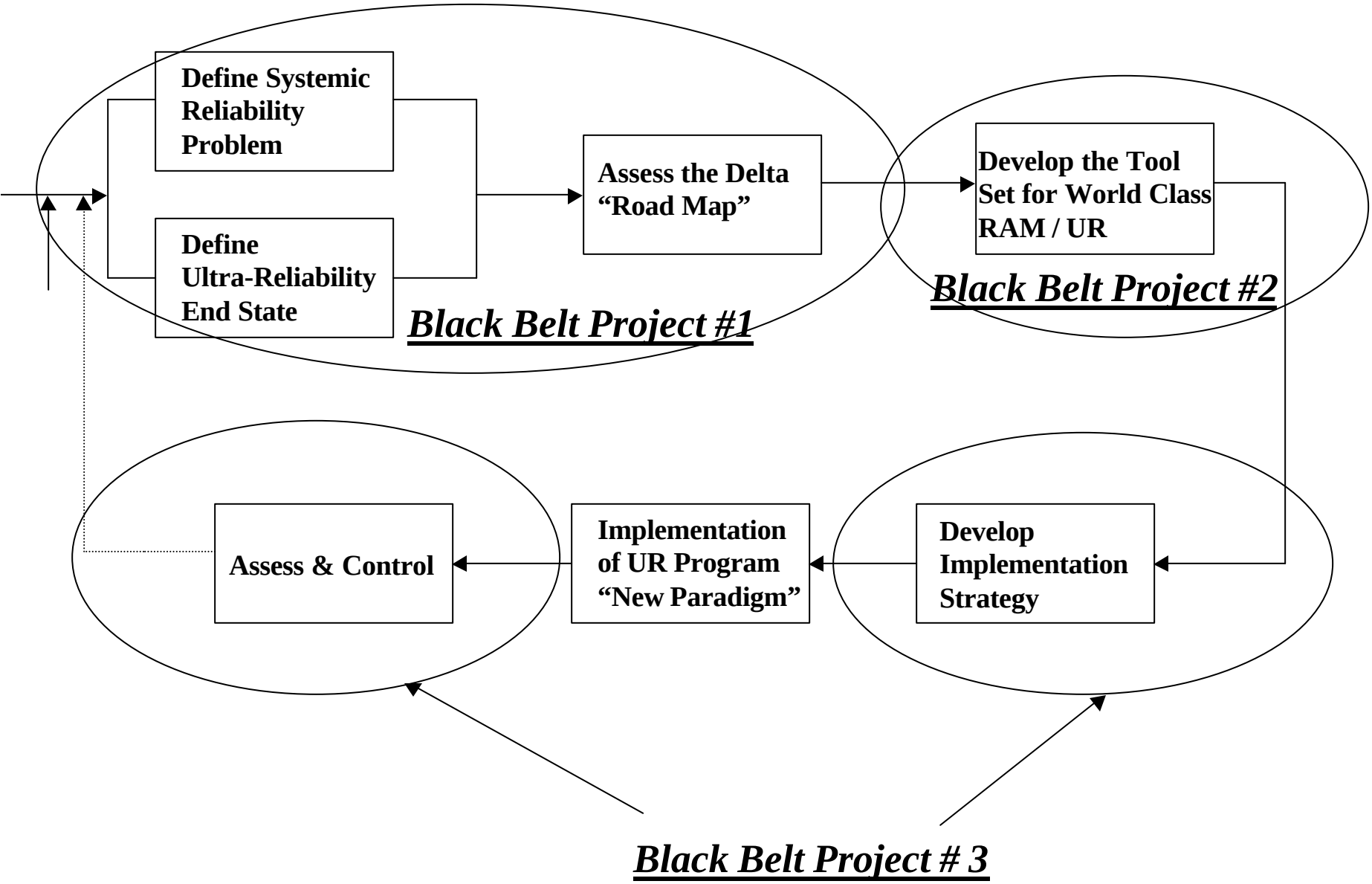
Simplified Process Flow Diagram



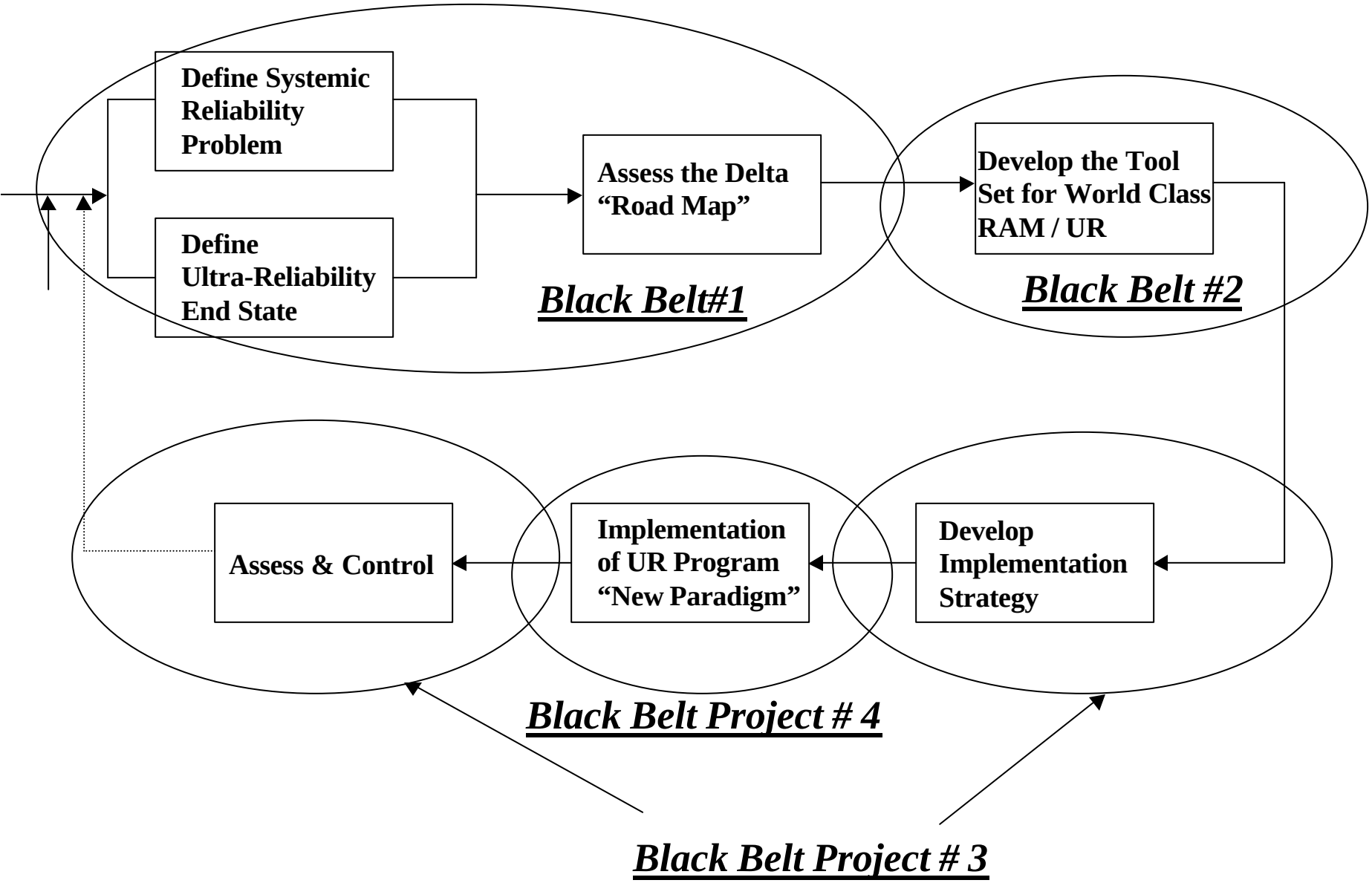
Simplified Process Flow Diagram



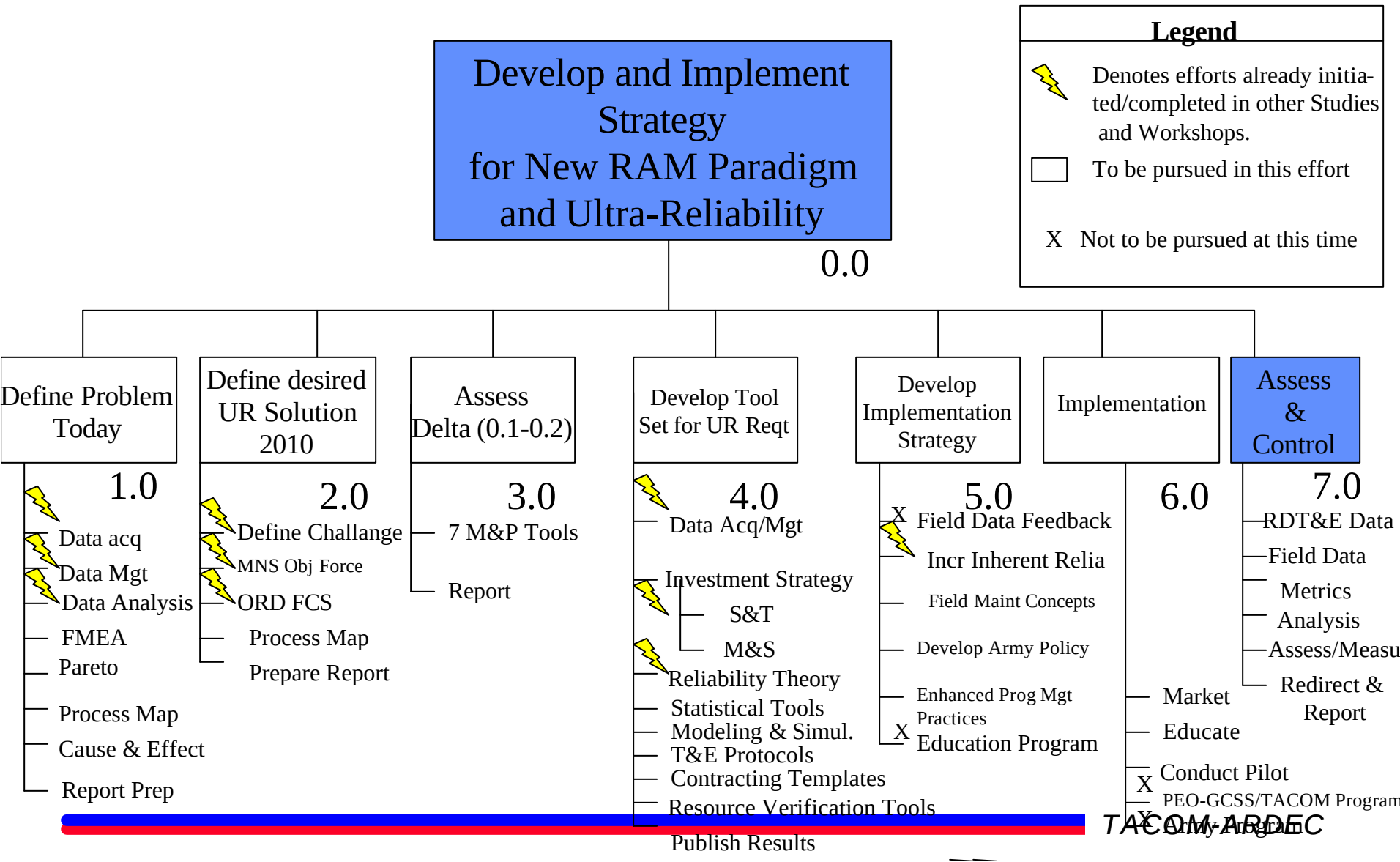
Simplified Process Flow Diagram



Simplified Process Flow Diagram



Six Sigma - WBS - Level 1



Summary

- **Without significant changes, Objective Force equipment will likely experience the same level of unreliability as current weapon systems. We MUST create a Paradigm change and maintain the discipline to continuously improve.**
- **Reliability must be designed in upfront**
  - **The tools and technology exist.**
  - **Strategies and "Standards of Practice" can be orchestrated for success with Disciplined implementation.**
  - **High reliability does not need to come with a high price tag.**
- **Need a strong Army Team, Champions, and Change Agent**
- **Contracting for reliability is key. If reliability is not a specific contractor priority, then we will likely not receive a reliable product.**
- **Discipline in the form of 6 Sigma and Capability Maturity Model (CMM) being used for program and organizational success assurance.**
- **Official Army Pilot Program – target 30 June 02**